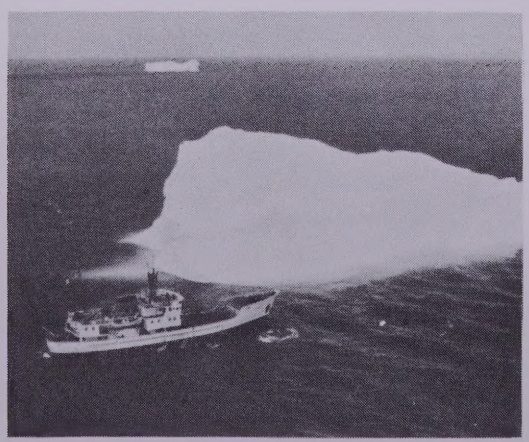
OCEAN ENGINEERING GROUP
WORK IN PROGRESS

Faculty of Engineering and Applied Science
Memorial University of Newfoundland

March 1982

CONTENTS



Front Cover: Iceberg Profiling and Draft Measurement aboard CSS Dawson

Cover art work and report layout by Hanny Muggeridge.

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OCEAN ENGINEERING GROUP

WORK IN PROGRESS

Compiled and edited by
T.R. CHARI
from contributions and research descriptions by individual researchers.

Faculty of Engineering and Applied Science
Memorial University of Newfoundland
St. John's, Newfoundland, Canada A1B 3X5

DEDICATED TO
THE 84 HEROIC MEN
WHO WENT DOWN WITH
THE DRILL RIG "OCEAN RANGER"
FEBRUARY 15, 1982
ON THE GRAND BANKS
AND TO ALL OTHER PIONEERS
WHO SACRIFICED THEIR LIVES AT SEA
IN SEARCH OF PROGRESS.

PREFACE

This edition of WORK IN PROGRESS summarizes the research activities during 1981 and the ongoing work for 1982 in the Ocean Engineering Group of the Faculty of Engineering at Memorial University of Newfoundland. Details of the various research projects and copies of the publications may be obtained by writing Dr. T.R. Chari, Chairman of the Research Group, or by addressing the individual researchers who are listed in the report.

Aerial view of the University campus looking East: Engineering Building first on the left.

INTRODUCTION

The Ocean Engineering Group has a present strength of 30 full-time professors drawn from the Civil, Electrical, Mechanical, Shipbuilding and Applied Mathematics disciplines of the Faculty of Engineering and Applied Science at Memorial University. Members of the group have research interests in ocean-related problems allied to their discipline of specialization. A list of the members and their current projects is given at the end of this booklet.

THE RESEARCH ENVIRONMENT

The Ocean Engineering Group was established in 1969 and complements the other marine research groups at Memorial University, the Marine Sciences Research Laboratory (MSRL), the Centre for Cold Ocean Resources Engineering (C-CORE), Newfoundland Institute for Cold Oceans Sciences (NICOS) and the Arctic Vessel and Marine Research Institute (AVMRI). MSRL preceeded the Ocean Engineering Group and was started in 1968. C-CORE was established by the University in 1975 with the financial support of the Devonian Group of Foundations of Calgary. NICOS is a part of the Faculty of Sciences and directs its research effort towards Oceanography and Ocean Sciences and was established in 1979. The Ocean Engineering Group, MSRL, C-CORE and NICOS work in close cooperation with each other. AVMRI is being established by the National Research Council of Canada, will be located on the Campus of Memorial University adjacent to the Engineering Building, and will be a world-class ice engineering facility. The Newfoundland Ocean Research and Development Corporation (NORDCO) is a Crown Corporation and has an ongoing liaison with the Ocean Engineering Group.

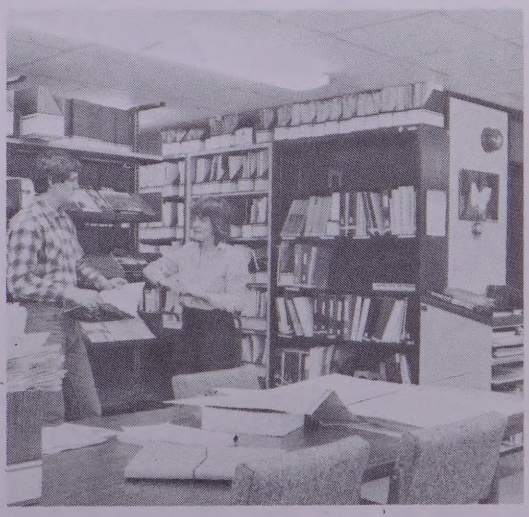
A chart of the various organizations in Newfoundland participating in ocean related activities is shown on the next page.

Ocean Engineering Information Centre

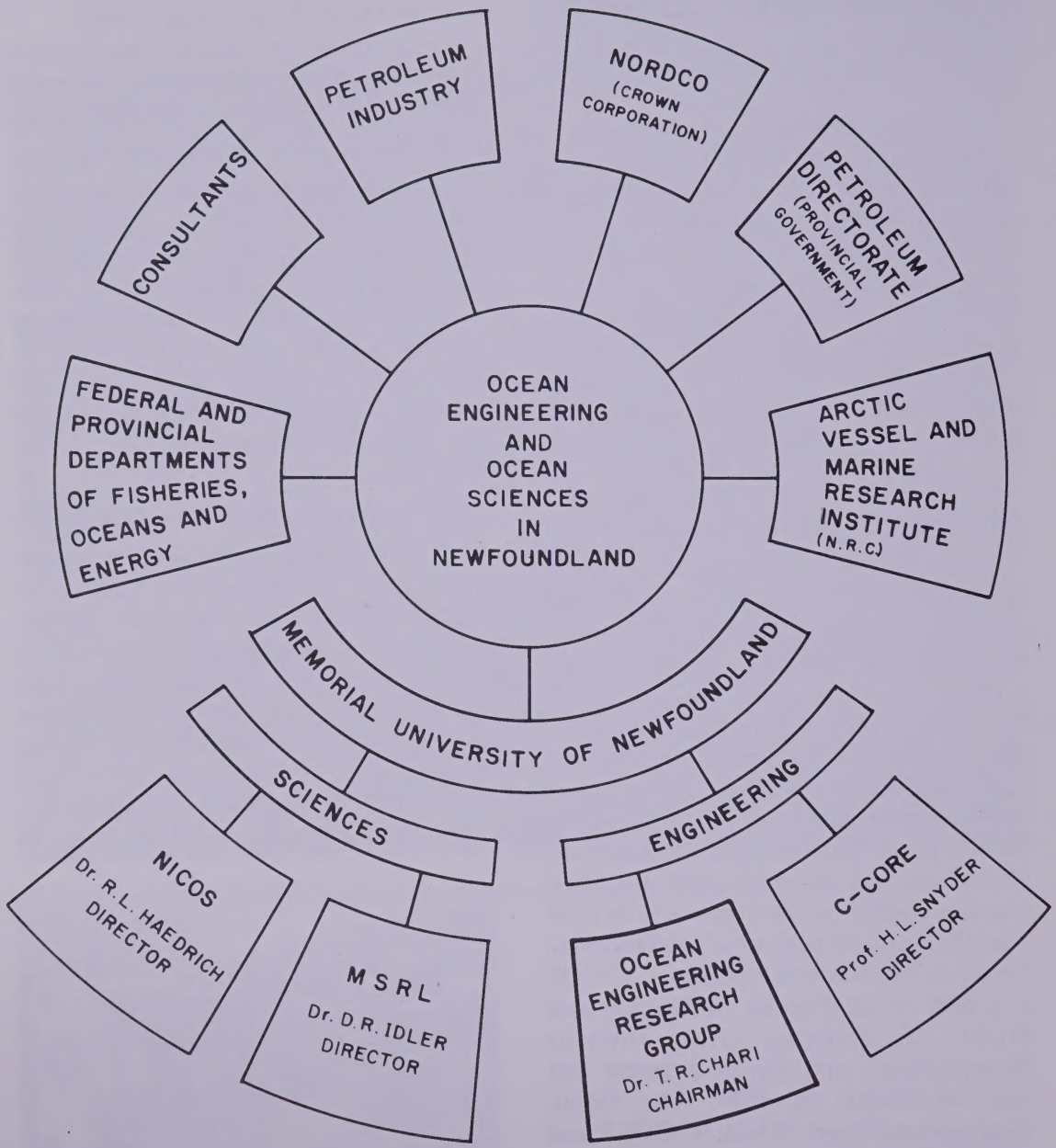
The Ocean Engineering Information Centre (OEIC) is jointly supported by C-CORE and the Ocean Engineering Group. This facility offers library and literature search support to the members of the various groups on Campus and by subscription to outside users. Ms. Judy Whittick who is the Head of this Centre may be contacted directly for further information.

Continuing Engineering Education Centre

The Continuing Engineering Education Centre (CEE) of the Faculty of Engineering offers several short courses and seminars on topics of relevance to offshore operations on the Canadian East Coast. These are advertised when offered and further details and listing of the courses may be obtained by writing Professor H.N. Ahuja who is the Director of Continuing Engineering Education. ■



Ocean Engineering Information Centre



Oceans Related organizations in Newfoundland

ACTIVITIES — 1981

ORGANIZATIONAL CHANGES

There have been several organizational changes since our last report. Cdr. C.D. diCenzo assumed the office of Dean of Engineering in September 1980. Dr. G.R. Peters is now the Associate Dean with overall responsibilities for Graduate Studies and Research in the Faculty of Engineering and Applied Science. Dr. T.R. Chari has assumed the responsibilities for the Ocean Engineering Group as its Chairman.

FACULTY

Dr. R.T. Dempster has returned from his sabbatical year in Scotland where he studied the economic impact of offshore oil development with particular reference to Newfoundland. Dr. R.M. Hopkins spent a sabbatical year studying the problem of corrosion in Marine Environment. Dr. D.B. Muggeridge returned from his sabbatical leave which he spent in the offshore industry and worked on several problems of interest to the Canadian offshore. Dr. M. Arockiasamy has now joined us as a full-time member of the Faculty of Engineering.

Drs. P.N. Smith and J. Walsh are currently on their sabbatical leave and are involved in joint research projects with C-CORE during this period. Drs. P.J. Amaria and D.V. Reddy are presently away on a leave of absence. Dr. J.D. Malcolm left in December 1981 to take a full-time research position in Alberta and Mr. W.L. White left in May 1981 to return to the consulting industry.

GRADUATE STUDENTS

There are at present 24 graduate students working on M.Eng. and Ph.D. dissertations in Ocean Engineering topics. The level of funding for graduate students in engineering is expected to be raised up to $10,000 commencing September 1982. In addition, C-CORE offers several fellowships to the value of $12,000 for graduate studies in Ocean Engineering. With the recent changes in the organizational structure, we expect to have a strong graduate program in Ocean Engineering in the coming years.

Mini cruise aboard ELSIE-G and Seatrials on Acoustic Telemetry

SCIENTIFIC CRUISES AND SEA TRIALS

The Ocean Engineering Group participated in joint sea trials with the Bedford Institute of Oceanography and C-CORE

during May 1981 aboard the research ship CSS BAFFIN. Dr. T.R. Chari, Prof. W.G. Smith, Mr. H.P. Green, Mr. W. Jacobs and Mr. A. Bursey of the Group participated. In-situ measurements were made of the seabed in the Hibernia area of the Grand Banks to evaluate the type of the ocean bottom and to correlate it with iceberg scour measurements by the Bedford Institute of Oceanography.

Seven one-day sea trials were organized by Dr. A. Zielinski with the University research ships ELSIE-G and KARL & JACKIE. Research on Multichannel Acoustic Telemetry and Underwater Digital Acoustic Communication System was carried out during these mini-cruises. Mr. D.E. Howse and Mr. W. Jacobs of the Ocean Engineering Group also participated.

Major sea trials planned for 1982 include ice scour studies in the Beaufort Sea on R/V KARLUK in cooperation with the U.S. Geological Survey and iceberg studies in the Labrador Sea on CSS HUDSON in cooperation with the Bedford Institute of Oceanography.

ARCTIC VESSEL & MARINE RESEARCH INSTITUTE

Construction activities on the National Research Council's Arctic Vessel and Marine Research Institute commenced in May 1981. The concrete foundation has now been laid and the erection of steel columns is in progress. The administrative wing of the building is scheduled for completion by 1982 and the entire facility is expected to be operational by 1984. Dr. G.R. Peters represents the interests of the University in the Advisory and Steering Committees of AVMRI. ■

Bedford Institute of Oceanography Research Ship CSS Baffin

SUMMARY OF RESEARCH PROJECTS

A summary of the major ongoing research areas in the Ocean Engineering Group is given below. Detailed description of the projects and their supervisors are given in the next section.

A. GEOTECHNOLOGY

Work has continued on the use of acoustic sensing to determine geotechnical properties of ocean sediments and on identification of subsurface layering. Emphasis has been on the development of computer models and processing algorithms. Analysis of corresponding core data and impact penetrometer calibration are also continuing.

B. ACOUSTICS, COMMUNICATION AND TELEMETRY

Some of the work under this heading is related to the previous section. Projects include the design of an underwater digital telemetry system, feasibility study of a deep-ocean system to measure Tsunami wave height, and the study of electromagnetic wave propagation over rough ocean surfaces. In conjunction with industry, a sonar azimuth positioning device is under development for use in obtaining the underwater shape and draft of icebergs. Work is in progress in building comprehensive models of VHF/UHF propagation to observe sea states and tides.

C. HYDRODYNAMICS

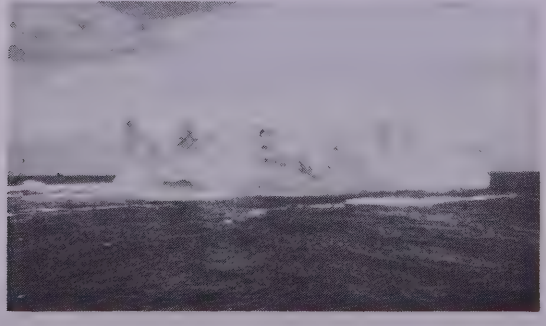
Projects include theoretical work on optimal ship forms for minimum total resistance and a study to compute the three-dimensional flow and wave resistance of a ship. Experimental work is in progress on hydroelastic response of plates and propeller blades vibrating in a fluid.

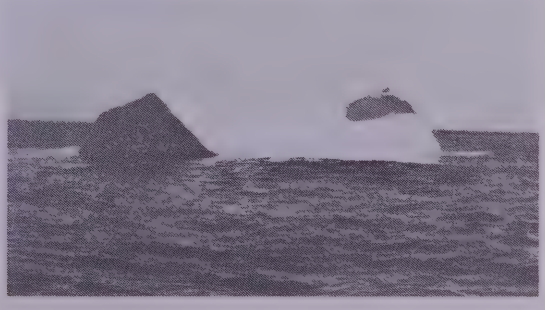
D. ICE AND ICEBERGS

A study of the effect of wind and waves is in progress to determine the relative importance of the different environmental parameters on iceberg drift. Sea trials were conducted jointly with the Bedford Institute of Oceanography to study the seabed characteristics in the Hibernia and Ben Nevis areas of the Grand Banks. Laboratory model tests of iceberg scouring are in progress. Experiments are also in progress to identify the factors affecting the melting process of icebergs.

Design work is proceeding on the test equipment for studying the friction between ice and other materials.

Theoretical and experimental investigations are being done on the fracture behaviour of freshwater ice. The effect of strain rate, grain size and temperature on the fracture toughness is being investigated.





Typical Icebergs on the East Coast

E. OCEAN STRUCTURES

Theoretical and experimental studies of semisubmersible drill rigs subjected to wave, wind, current and ice floe impact are in progress. Experiments are in progress with 1:70 scale model in the 60 m wave tank.

Fatigue and corrosion fatigue of welded tubular joints is being studied.

F. ENGINEERING AND ECONOMIC IMPACT STUDIES

Studies are in progress concerning the impact of the development of oil and gas fields on the Grand Banks and its effect on the construction industry. Models such as those used for similar studies in Europe and the data assessed from Scotland are being examined. ■

Iceberg Towing Experiments

DESCRIPTION OF RESEARCH PROJECTS

A detailed description of the various research projects is given below. The researchers associated with each project are also listed. Related publications are given in the next section and referenced at the end of each research description.

A. OCEAN GEOTECHNOLOGY

A1. Ocean Sediment Properties Using Acoustic Sensing (W.J. Vetter, A. Zielinski, T.R. Chari)

Acoustic methods for ocean sediments have the advantage of being fast but they lack immediate correlation with the geotechnical properties. Several advances have been made in recent years in ground truthing by conventional techniques. This includes equipment like the electric penetrometer which can give the penetration resistance of the soil continuously. Seabed data were collected by the Ocean Engineering Group during seatrials in 1978 over a length of 1000 line km in Placentia Bay in different types of sediments using several acoustic and ground truthing techniques. These data are being used to investigate the possible correlation of the geophysical and geotechnical properties of marine sediments. Models have been developed for multiple subbottom reflections and effects of acoustic impedance profile. Several processing algorithms have been developed for data enhancement and correction. [References 2, 31-33, 36-42, 91-97, 104-107]

A2. In-Situ Soil Tests Using a Free Fall Penetrometer (T.R. Chari, W.G. Smith)

A free fall penetrometer has been developed and tested during the past few years. The development of the penetrometer has progressed further and a 7 m long penetrometer was tested in the Hibernia area of the Grand Banks during sea trials in May 1981. The penetrometer is now being instrumented with a self-recording microprocessor which will eliminate the need for the umbilical cable. Penetrometer tests will be continued during 1982. Further laboratory tests with soils of known properties are in progress. [References 1, 12, 14, 19, 22, 25, 26, 38, 107]

A3. Seabed Stability and Bearing Capacity (T.R. Chari, C.R. Dawe*, J.S. Joo*)

Theoretical and experimental studies have been initiated on the wave and shock effects on seabed stability with particular reference to the Grand Banks. This project is a cooperative effort with C-CORE.

Field Tests with the Penetrometer

Unlike those on land, pile foundations in the ocean environment are subject to large lateral and cyclic loads. Studies have been started to conduct experiments on rigid and flexible piles in sand and clay, subjected to lateral loads. [References 3, 18]

B. OCEAN ACOUSTICS, COMMUNICATION, TELEMETRY AND INSTRUMENTATION

B1. Swept Carrier Underwater Acoustic Communication System and Digital Telemetry (A. Zielinski, R.L. Barbour*, E.D. Howse**)

A new concept of information transmission in an underwater multipath environment has been developed and successfully tested during the May 1978 sea trials. A significant improvement over conventional transmission schemes was demonstrated. Using similar principles, the analytical and physical models for multipath channels are now being developed.

A prototype of the digital telemetry for the above concept has been built and tested at sea. The results of the tests will affect future system modifications and the direction of theoretical investigation of sound propagation. [Reference 10]

B2. Multichannel Acoustic Telemetry (A. Zielinski, S. Temple*, W. Jacobs**)

A multichannel analog acoustic telemetry system utilizing frequency-modulated carriers has been developed. The system has a potential use in conjunction with the free fall penetrometer for transmitting the three data channels without using an umbilical cable. Errors caused by ship heave are minimized by an optimal inertial compensation subsystem. The system was successfully tested at sea in 200 m water depths. [Reference 104]

B3. Sonar Azimuth Positioner (A. Zielinski, W. Jacobs**)

Acoustic sensing (sonar) devices used for iceberg profiling and draft measurements present operational difficulties caused by a random rotation of the transducer. The objective of this research is to develop a control system to position and to stabilize the underwater transducer in any desired direction. The system is to operate in 400 m water depths.

Deploying an Acoustic Telemetry System

This project is funded by a PRAI grant from the National Research Council of Canada. Ice Engineering Limited, St. John's is the industrial collaborator.

B4. Deep-Ocean System to Measure Tsunami Wave Height‡ (A. Zielinski)

Tsunamis are earthquake generated waves and the existing tsunami warning systems are based on seismic recordings and observation from the coastal tidal stations. It has been reported that two-thirds or more of all tsunami warnings are false alarms because they are based on seismic records. Prediction of tsunamis can be improved if the wave heights at various points can be measured in the deep ocean and relayed in real-time to a tsunami warning center.

The concept of an integrated system to measure tsunami waves in the deep ocean consists of detecting the pressure variation at the ocean bottom due to the change of sea level caused by an earthquake. The signals will be transmitted through an underwater acoustic telemetry link to an intermediate buoy and through stationary satellite to a tsunami warning centre. The ultimate objective of this research is to develop an integrated system to detect and measure deep ocean generated tsunamis in real time for early and reliable warning of endangered coastal areas. [Reference 84]

B5. Electromagnetic Wave Propagation Over Ocean Surfaces (J. Walsh)

The state-of-the-art to use V.H.F. radio for the transmission of data collected underwater is somewhat limited. The problem can be traced to inadequate height at the transmitting antenna. Research at Memorial University is focussed on finding a reliable model of electromagnetic waves over rough surfaces including the ocean. An integral equation approach shows good promise of a solution. The final objective is the design of a reliable telemetry system in the ocean environment.

A related experimental project sponsored by the Department of Communications, Ottawa is the recording of VHF signal strengths over at least two paths of different lengths over seawater for a period of one year and to study the effects of parameters such as the sea-state and weather conditions. At least two paths of different lengths will be instrumented and three frequencies sampled, in the low and middle VHF and low UHF respectively. The data collected will be correlated with observed variables such as sea state, meteorology and tides. [References 99, 100]

B6. An Evaluation of HF Radars for the Detection of Sea Ice Hazards and the Measurement of Ocean Wave Spectra (J. Walsh, R. Donnelly*, J. Ryan*, S. Srivastava*)

A new analytical approach to the electromagnetic rough surface problem has been developed and for surfaces with periodic profiles (such as the ocean surface) series solutions have been constructed and convergence demonstrated. These solutions are being extended to the problem of remote sensing of ocean wave directional spectra by high frequency (HF) radar. The analytical techniques discussed above can be used to develop a model capable of predicting HF surface wave propagation and scatter with respect to an ice-infested ocean.

The results of this modelling effort should determine the feasibility of specifying a HF radar system capable of detecting significant backscatter from large consolidated ice features. The analytical work will be supported by a number of field experiments in cooperation with C-CORE. This system is planned to be operational in 1982. [References 98-100]

B7. Remote Sensing of Sea Ice (D. Bajzak)

Research is in progress in obtaining sea ice and sea surface data using pictorial and digital images of aerial photography and satellite imagery. The techniques of analysis include the use of a VP-8 image analyzer, a scanning micro-densitometer and computer processing.

C. MARINE HYDRODYNAMICS

C1. Computer Simulation of Wave Loads and Motions of Offshore Floating Structures in Waves (C.C. Hsiung, H. El-Tahan*)

This research is to study the stability of stationary vessels such as floating drill rigs in both regular and irregular waves under extreme 100 year wave conditions. The effects of the first and second order wave forces will be evaluated. Motions and mooring loads on single vessels as well as the connecting elements between the storage vessel and shuttle tanker, are to be modelled.

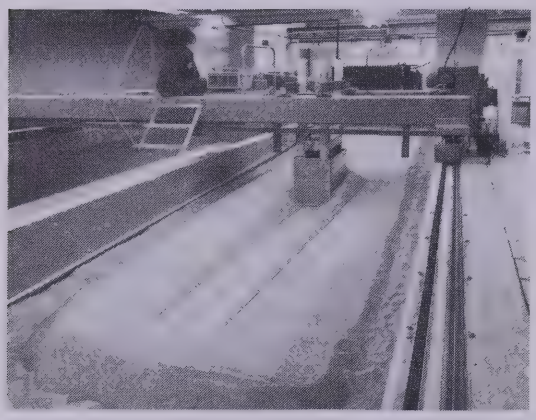
C2. Optimal Ship Forms for Minimum Total Resistance (C.C. Hsiung, Dong Shengyan=)

A numerical scheme is being devised to compute the wetted surface area of a ship-hull. The frictional resistance of a ship can be expressed in terms of the ship-hull offsets for a given design speed and incorporated into a single expression which will include the wave resistance. Optimal ship forms of minimum total resistance can be generated by applying a quadratic programming method to the resulting equations. [Reference 58]

C3. Computing Three-Dimensional Flow and Wave Resistance of a Ship (C.C. Hsiung, D. Sen*)

The three-dimensional flow and wave resistance of a ship is being modelled in order to determine the effects of parameters such as

flow velocity vectors on the hull, wave profile along the hull and the sinkage and trim of the ship at a constant speed. The computational scheme will be based on the "thin-ship" theory and the "Neumann-Kelvin problem". [Reference 57]



Iceberg Scour Model Tests

C4. Dynamic Response of Plates and Propeller Blades Vibrating in a Fluid (M. Booton)

An experimental research programme for determining the response of flat plates and propeller blades vibrating in air and in water has been carried out. The test method consists of driving the base of the blade with a random force input (band limited white noise) and measuring the output acceleration at a point. Plots of transfer functions (frequency response) and coherence were obtained for a rectangular plate and a model of a highly skewed propeller blade. The Defence Research Establishment Atlantic (DREA) is cooperating in this investigation.

D. ICE AND ICEBERGS

D1. Stability of Icebergs (D.B. Muggeridge, W.E. Russell, N.P. Riggs*)

A study of the stability and hydrodynamic characteristics of icebergs has been initiated. Experimental work is in progress to evaluate the various parameters including the drag coefficient. [Reference 83]

D2. Iceberg Drift (R.T. Dempster, C.C. Hsiung, A.F. Aboul-Azm*)

A numerical model has been developed to predict the iceberg drift trajectories from the known or derived information regarding the iceberg characteristics and the environmental forces affecting the motion of an iceberg, such as the forces due to winds, currents, Coriolis effect, geostrophic effect and waves. The model has given satisfactory results for tabular icebergs. Modelling for other iceberg configurations is in progress. [References 35, 43, 59, 85]

D3. Iceberg Scour (T.R. Chari, G.R. Peters, A.S. Reddy †, H.P. Green**)

Mathematical and physical models have been developed for iceberg scouring of the seabed. Extension of the mathematical model to different soil types and icebergs of various shapes is in progress. Testing of 50 cm wide physical model in a 14 m x 6 m tank is in progress. Tests are also in progress with buried pipelines to delineate the zone of influence of the scouring phenomenon. [References 13, 15, 16, 17, 20, 21, 23, 24, 45, 64, 73]

D4. Iceberg Melting (B.D. Bowen, C.R. Dutton**)

The below-waterline melting of icebegs is controlled by the transfer of heat from the bulk seawater by natural convection. Theoretical studies of the laminar natural convection melting of semi-infinite vertical ice sheets in fresh and saline waters have been completed. Two complementary experiments are presently underway to help identify the importance of parameters such as fluid turbulence, entrapped air bubbles, air-water interface and inclined surfaces. In one, velocity, temperature and salinity distributions near a vertical ice sheet are measured while in the other, the melt profiles of vertical ice cylinders and the associated natural convection flow patterns are obtained by time-lapse photography. [References 56, 61, 87, 88, 101-103]

D5. Monte Carlo Simulation of Iceberg Shapes and their Impact Probabilities (D.V. Reddy, M. Arockiasamy, P.S. Cheema+)

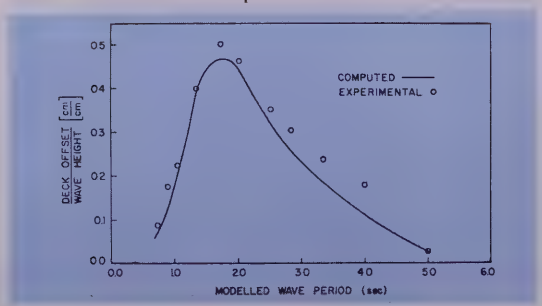
In order to establish the risk factors involved in drilling operations in the Labrador Sea, it is necessary to establish the iceberg impact probabilities. In this research, the Monte Carlo method is being used to simulate the above-water and below-water profiles based on a set of observed icebergs. A Monte Carlo type Fault Tree analysis is then applied to determine the iceberg impact probabilities for this extended data base. [Reference 77]

D6. Ice Friction (J. Molgaard, P.N. Smith, L.C. Wong**, R.M. Harvey*)

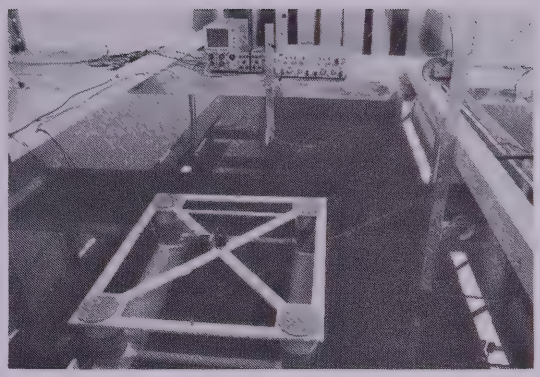
Design work is proceeding on test equipment for studying the friction between ice and other materials. The ice samples used will range in size up to a diameter of about 10 cm. Other test parameters are normal loads up to at least 10,000 N at sliding speeds from zero to 10 km/h and temperatures between -40° C and 0° C. The test materials and surfaces will be typical of those in commercial use at the water line on ice breakers, other ships and stationary structures in ice-infested waters. [Reference 60]

D7. Ice Mechanics (D.B. Muggeridge, H. Hamza*, A.A. Tehrany*)

A theoretical and experimental program has been undertaken to investigate the creep and fracture behaviour of fresh water ice covers. The finite element method was used to solve the nonlinear problem of creep bending of a plate. An isoparametric thick plate element was used and good agreement was obtained between the present work and the results available in published literature.



Results of model study of a Guyed Tower



Wave Tank studies of a model Semisubmersible

Experimental studies have been undertaken to evaluate the fracture toughness of ice in terms of the critical value of the stress intensity factor in the opening mode of failure. The effects of strain rate, grain size and temperature on the fracture toughness of fresh water and saline ice are being investigated. [References 51-55, 86]

E. OCEAN STRUCTURES

E1. Wave Force on Structures (D.B. Muggeridge, V.M. Arunachalam★, J.J. Murray**, O. Grande*)

Model studies of fixed and floating structures, subjected to regular and irregular waves, have been undertaken. These include a group of eight cylindrical piles and a guyed tower. Wave forces were measured on each of the eight cylinders and the values of C_D and C_M were obtained as a function of Keuligan Carpenter Number. A theoretical and experimental study of the deck offset of a guyed tower in regular waves has been made. This program is being extended to look at the dynamic response of the same tower to irregular waves. [References 9, 65-72]

E2. Structural Integrity Monitoring of Fixed Offshore Platforms (M. Booton, A.J. Christian, M.A. Marshall*)

The purpose of the research programme is to determine techniques for monitoring vibrations of fixed offshore platforms subjected to ocean waves and to assess the change in the vibration spectrum caused by a secondary structural failure. Tests were conducted in air with a K-frame type tower constructed from PVC tube. The vibration

spectrum of the undamaged tower was determined experimentally and the resonant frequencies obtained were compared with analytically determined values. The procedures were repeated with one or more members removed from the structure. The shift in the resonant frequencies of the "damaged" tower was observed.

E3. Dynamic Structure-Soil-Water Interaction Studies (D.V. Reddy, M. Arockiasamy, A.S.J. Swamidas†, K. Munaswamy★, H. El-Tahan*, A.K. Haldar*)

a. Dynamic Response of Semi-Submersibles:

This research is to evaluate the response of semi-submersible structures operating in the ice-infested waters under the combined effect of ice impact, wind, wave and current forces. Finite element structural modelling is carried out synthesizing motion and structural responses complemented by coupled and uncoupled response analyses. These results are being varified by studies on experimental 1:70 scale models.

Ice forces are estimated from theoretical models as well as actual ice force records simulating successive impacts. The wave and wind forces are determined from the force spectra and the cable nonlinearity is considered using a piece-wise deformation model.

b. Offshore Platform Foundation Shakedown Analysis

A finite element formulation is proposed for the shakedown analysis of a foundation-soil medium with particular reference to a gravity monopod offshore platform. The method is based on a dynamic finite element formulation for a fluid-saturated porous medium.

A shakedown load factor is determined using a piece-wise linearized convex yield surface in the dynamic finite element displacement formulation. The sensitivity of the shakedown load factor to parametric variation of the soil properties is determined by a specially developed computer code. [References 4-8, 11, 46-50, 62, 63, 74-82, 89, 90]

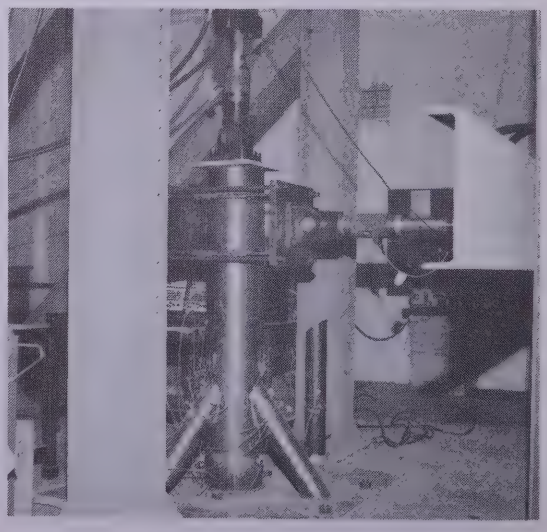
E4. Experimental and Analytical Studies on Fatigue (D.V. Reddy, M. Arockiasamy, S.S. Gowda*)

An experimental and analytical investigation of the static and fatigue behaviour of tubular joints for offshore structures is being carried out. The test specimens are designed based on the steel monopod tower built in Cook Inlet, Alaska. Both axial and lateral loads are applied and the results correlated with finite element analysis which includes automatic mesh generation. [Reference 44]

F. ENGINEERING AND ECONOMIC IMPACT OF OFFSHORE OIL AND GAS

F1. Impact of Offshore Oil and Gas on the Newfoundland Construction Industry (A.J. Christian)

The purpose of this research is to study the impact of the development and production of the potential oil fields off the Newfoundland and Labrador Coast on the construction industry in Newfoundland. The impact of North Sea Oil production in Norway and Scotland is being examined as representative models. The research has been organized into five sections, which will include various aspects of the oil development and the construction and management techniques. [References 27-30]



Fatigue Behavior of Welded Tubular joints

F2. Economic Consequences of Oil and Gas Development in Newfoundland (R.T. Dempster)

Five areas of oil and gas development listed below were studied during a one-year sabbatical leave in Scotland and Norway.

a) Government structure and administration related to oil and gas

b) Education and training

c) Social structure and organization

d) Technology development (R&D and Industry)

e) Spin-off development of small technological business.

Results of these studies are now being evaluated for Newfoundland. [Reference 34]

*Graduate Student
**Project Engineer
‡Joint Project with Dr. N.K. Saxena, Department of Civil Engineering, University of Hawaii
=Visiting Scholar
†Visiting Research Fellow
+Research Assistant
★Post Doctoral Fellow ■

OCEAN ENGINEERING GROUP AND RESEARCH INTERESTS

H.N. Ahuja, B.A. (Punjab), M.A.Sc. (Waterloo), F.I.E. (India), P.Eng.	Management of Ocean Projects
P.J. Amaria, D.M.S. (Aston), Ph.D. (Birmingham), P.Eng.	Systems Analysis, Fisheries
M. Arockiasamy, B.E., M.Sc., (Madras), Ph.D. (Wisconsin)	Structural Analysis, Ice Forces
D. Bajzak, B.Sc.F., M.F. (British Columbia), Ph.D. (Syracuse), P.Eng.	Ice, Ocean Currents, Remote Sensing
M. Booton, B.A.Sc., M.A.Sc., Ph.D. (Toronto), P.Eng.	Vibrations of Structures, Fluids
B.D. Bowen, B.A.Sc., Ph.D., (British Columbia)	Fluid Dynamics, Ice
M.P. Bruce-Lockhart, S.B., S.M., (M.I.T.), P.Eng.	Microprocessors, Data Acquisition
W.J. Campbell, B.Eng., (Nova Scotia), M.A.P.A. (Oklahoma), M.A.Sc. (Waterloo), P.Eng.	Strait of Belle Isle
++T.R. Chari, B.Eng. (Madras), M.Tech., (Kharagpur), Ph.D. (M.U.N.), P.Eng.	Marine Geotechnology, Marine Foundations, Iceberg Scour
A.J. Christian, B.Eng. (Sheffield), Ph.D. (Bradford), M.I.C.E., P.Eng.	Impact of Offshore Oil on Construction Industries
R.T. Dempster, B.Sc. (Strathclyde), M.Sc. (Birmingham), Ph.D. (Toronto), P.Eng.	Fluid Dynamics, Icebergs, Ocean Engineering
C.D. diCenzo, C.M., C.D., M.Sc. (New Brunswick), D.I.C. (Imperial College), F.E.I.C., F.I.E.E.E., V.I.E. (Australia), P.Eng.	Marine Engineering, Ocean Engineering
H.J. Dyer, B.E., M.Eng. (Nova Scotia), P.Eng.	Iceberg Dynamics
D.A. Friis, B.Sc. (Newcastle), M.B.A. (Toronto), Siv. Ing.	Ocean Transportation, Shipbuilding
R.M. Hopkins, B.Eng. (Nova Scotia), M.S. (Maine), Ph.D. (British Columbia), P.Eng.	Corrosion
C.C. Hsiung, B.Sc. (Taiwan), M.Sc. (Michigan), Ph.D. (California), P.Eng.	Naval Architecture, Hydrodynamics
H.L. Krein, B.A.Sc., M.A.Sc., Ph.D. (Waterloo), P.Eng.	Submersibles
W.J. Milne, B.Sc. (M.I.T.), P.Eng.	Shipbuilding

++Chairman of the Research Group

J. Molgaard, B.Sc. (Belfast), Ph.D. (Leeds), P.Eng.	Ice Friction
E. Moore, B.Sc. (Edinburgh), B.Sc. (St. Andrews), Ph.D. (Waterloo), P.Eng.	Iceberg Dynamics, Applied Mathematics
D.B. Muggeridge, B.S. (California), M.A.Sc., Ph.D. (Toronto), P.Eng.	Ocean Structures, Fluids, Wave Tank
R. Niefer, B.Sc., Ph.D. (Windsor)	Fluid Dynamics, Applied Mathematics
G.R. Peters, B.Sc. (M.U.N.), B.A.Sc. (Toronto), Ph.D. (Aberdeen), P.Eng.	Ocean Engineering, Fisheries
M.A. Rahman, B.Sc. (Bangladesh), M.A.Sc. (Toronto), Ph.D. (Carleton), P.Eng.	Ocean Energy Systems
D.V. Reddy, B.E. (Madras), D.I.C. (Imperial College), M.Sc. (Northwestern), Ph.D. (Liverpool), P.Eng.	Structural Analysis, Ice Forces
P.N. Smith, B.Eng., M.Eng., Ph.D. (McMaster), P.Eng.	Ice Properties, Materials
W.G. Smith, B.Sc. (New Brunswick), P.Eng.	Mechanical Development
W.J. Vetter, B.A.Sc. (Toronto), M.A.Sc. Ph.D. (Waterloo), P.Eng.	Underwater Acoustics, Sediment Seismic Analysis and Signal Processing
J. Walsh, B.Eng. (Nova Scotia), Ph.D. (Calgary)	Ocean Communciations
A. Zielinski, B.Eng., M.Sc., Ph.D., (Wroclaw), P.Eng.	Underwater Telemetry, Instrumentation, Signal Processing

RECENT AND CURRENT GRADUATE STUDENTS IN OCEAN ENGINEERING

Name	Supervisor	Thesis Title	Remarks
Abdel-Gawad, S.T. (M.Eng.)	W.L. White	Correlation between Geotechnical and Acoustic Properties of Marine Sediments — Outer Placentia Bay, Newfoundland	Completed 1981
Aboul-Azm, A.F. (M.Eng., PT)	C.C. Hsiung	Iceberg Drift Affected by Wave Action	
Azedeh-Tehrany, A.R. (M.Eng.)	D.B. Muggeridge	K_{IC}Values for Saline Ice	
Babu, P.V.T. (Ph.D.)	D.V. Reddy	Application of Finite Element Method of the Analysis of the Ocean Structure	Completed 1981
Barbour, R.L. (M.Eng.)	A. Zielinski	Underwater Acoustic Swept Carrier Communications	Completed 1981
Dawe, B.R. (M.Eng., PT)	D. Bajzak	Processing of Side Looking Airborne Radar Data as Applied to Ice Research	
Dawe, C.R. (M.Eng.)	T.R. Chari	Marine Slope Stability with particular reference to the Canadian East Coast	C-CORE Fellow
Donnelly, R. (M.Eng.)	J. Walsh	Electromagnetic Scattering from the Ocean Surface	
Dutton, C.R. (M.Eng., PT)	B.D. Bowen	Normal Convection Melting of a Semi-Submerged Vertical Ice Wall	
El-Hawary, F. (Ph.D.)	W.J. Vetter	Object and Feature Profiling by Spatial Sonar Processing	Completed 1981
El-Tahan, H. (Ph.D.)	M. Arockiasamy D.V. Reddy	Dynamic Analysis of Semi-submersibles	
El-Tahan, M. (M.Eng.)	D.S. Sodhi	Modelling of Iceberg Drift	Completed 1980
Gowda, S.S. (Ph.D.)	M. Arockiasamy D.V. Reddy	Fatigue Analysis of Tubular Joints for Offshore Structures	
Grande, O.H. (M.Eng.)	D.B. Muggeridge	Analysis of Ice Forces on Ocean Structures	
Green, H.P. (M.Eng., PT)	T.R. Chari	Iceberg Scour Modelling	
Haldar, A.K. (Ph.D.)	M. Arockiasamy D.V. Reddy	Dynamic Water-Soil-Structure Interaction with Particular Reference to Soil Shakedown	
Hamza, H. El.S. (Ph.D.)	D.B. Muggeridge	Creep, Failure and Fracture of ice	
Harvey, R.M. (M.Eng.)	P.N. Smith	Friction Studies with the Metal Gallium	
Howse, D.E. (M.Eng.)	A. Zielinski	Digital Underwater Acoustic Communication System	
Joo, J.S. (M.Eng.)	T.R. Chari	Offshore Pile Foundations	
Marshall, M.A. (M.Eng.)	A.J. Christian M. Booton	Structural Integrity Monitoring of a Fixed-Bottom Tower	
Murray, J.J. (M.Eng.)	D.B. Muggeridge	Motion Analysis and Model Study of A Guyed Tower Structure in Regular Waves	

Ransom, J.A.N. (M.Eng., PT)	C.P. Benedict	Ice Blasting — An Overview	
Riggs, N.P. (M.Eng., PT)	D.B. Muggeridge W.E. Russell	A Theoretical and Physical Model of Iceberg Drift	
Ryan, J.P. (M.Eng.)	J. Walsh	The Detection of Ice Hazards with Ground Wave Radar	C-CORE Fellow
Sen, D. (M.Eng.)	C.C. Hsiung	Added Wave Resistance on an Ocean Going Barge	
Srivastava, P.K. (M.Eng.)	N.W. Wilson	Buoyancy Effects on Heat, Mass and Momentum Transfer During the Melting of a Horizontal Ice Sheet above Fresh or Saline Water Flowing at Laminar Reynolds Numbers	Completed 1980
Srivastava, S.K. (Ph.D.)	J. Walsh	Measurement of Sea State Using the Technique of H.F. Scattering from Ocean Surface	
Stone, B.M. (M.Eng., PT)	D.B. Muggeridge	Response of Floating Structures to Wave Loading	
Will, R.S. (M.Eng., PT)	B.D. Bowen	Investigation of Migration of Oil-Water Mixtures through Porous Material	
Wishahy, M.A. (M.Eng.)	M. Arockiasamy D.V. Reddy	Dynamic Analysis of Offshore Structures	
Worsfold, R.D. (M.Eng., PT)	A. Zielinski	Infrared Detection of Sea Ice Hazard	

PT: Part-time registration.

LIST OF RECENT PUBLICATIONS AND REPORTS

1. S.M. Abdel Gawad., "Static Penetration Resistance of Soils". *M.Eng. Thesis;* Memorial University of Newfoundland, St. John's, Aug. 1979.
2. S.T. Abdel Gawad., "Correlation Between Geotechnical and Acoustic Properties of Marine Sediments". *M.Eng. Thesis;* Memorial University of Newfoundland, St. John's, April 1980.
3. M.N. Abdel Salam., "Soil Structure Interaction in Laterally Loaded Piles". *M.Eng. Thesis;* Memorial University of Newfoundland, St. John's, August, 1979.
4. B.L. Aboustit., "Finite Element Linear Programming Approach to Foundation Shakedown". *M.Eng. Thesis;* Memorial University of Newfoundland, St. John's, September 1979.
5. B.L. Aboustit and D.V. Reddy., "Finite Element Linear Programming Approach to Foundation Shakedown". Proceedings, *International Symposium on Soils Under Cyclic and Transient Loading,* Swansea, U.K., January 1980, pp. 727-738.
6. M. Arockiasamy, D.V. Reddy, W. Bobby and A.K. Haldar., "Comparison of Finite Element and Lumped Parameter Modelling for Seismic Response of Reactor Building-Foundation Systems". Proceedings, *Third International Conference on Numerical Methods in Geomechanics,* Aachen, West Germany, April 1979, pp. 817-829.
7. M. Arockiasamy, P.V. Thangam Babu, D.V. Reddy., "Probabilistic Seismic Fluid-Structure Interaction of Floating Nuclear Plant". Proceedings, *Fifth International Conference on Structural Mechanics in Reactor Technology,* Berlin, Aug. 1979, Paper K4/7.
8. M. Arockiasamy, D.V. Reddy and P.S. Cheema., "Response of Offshore Toweres to Strong-Motion Earthquakes", *Sixth National Meeting of the Universities Council of Earthquake Engineering Research* (UCEER), Urbana, Illinois, May 1980, pp. 215-217.
9. V.M. Arunachalam, J.J. Murray and D.B. Muggeridge., "Flow Induced Interflow Between Circular Cylinders Subjected to Ocean Waves and Currents — A Review". *Oceans '81 Conference Record,* IEEE-MTS Conference, Boston, Sept. 1981, pp. 943-951.
10. L. Barbour., "Undewater Acoustic Swept Carrier Communication". *M.Eng. Thesis;* Memorial University of Newfoundland, St. John's, 1979.
11. W. Bobby, M. Arockiasamy, A.K. Haldar and D.V. Reddy., "Finite Element Analysis of Pipe-Soil-Wave Interaction". Proceedings *Conference on Behaviour of Offshore Structures* (BOSS), London, England, Aug. 1979., pp. 503-506.
12. T.R. Chari, W.G. Smith and S.N. Chaudhuri., "Development of Free Fall Penetrometer". *Oceans '81 Conference Record,* IEEE-MTS Conference, Boston, Sept. 1981, pp. 678-682.
13. T.R. Chari., "Iceberg Scour Factors on East Coast Production", *Drilling Canada,* Vol. 2, No. 4, July-August 1981, pp. 55-56.
14. T.R. Chari and S.M. Abdel-Gawad., "Static Penetration Resistance of Soils". Proceedings of POAC '81, *International Conference on Port and Ocean Engineering Under Arctic Conditions,* Quebec City, July 1981, pp. 717-725.
15. T.R. Chari and H.P. Green., "Iceberg Scour Studies in Medium Dense Sands". Proceedings of POAC '81, *International Conference on Port and Ocean Engineering Under Arctic Conditions,* Quebec City, July 1981, pp. 1012-1019.
16. T.R. Chari and G.R. Peters., "Engineering Challenges in the Cold Oceans". *Journal of the Society for Underwater Technology,* Vol. 7, No. 1, March 1981, pp. 8-13.
17. T.R. Chari and G.R. Peters., "Estimates of Iceberg Scour Depths". Invited paper for Panel Discussion, Proceedings of the *Symposium, Production and Transportation Systems for the Hibernia Discovery,* St. John's, Newfoundland, February 1981, pp. 178-188, 432-455.
18. T.R. Chari and M.N. Abdel-Salam., "Laterally Loaded Offshore Piles; Comparison of Finite Difference and Finite Element Analyses". Proceedings *First Indian Conference in Ocean Engineering,* Madras, February 1981, pp. III 69 - III 74.
19. T.R. Chari, S.M. Abdel-Gawad and S.N. Chaudhuri., "Laboratory Tests with a Marine Penetrometer", Proceedings *First Indian Conference in Ocean Engineering,* Madras, February 1981, pp. III 59 - III 64.
20. T.R. Chari., "A Model Study of Iceberg Scouring in North Atlantic". *Journal of Petroleum Technology,* Vol. 32, December 1980, pp. 2247-2252.
21. T.R. Chari, G.R. Peters and K. Muthukrishnaiah., "Environmental Factors Affecting Iceberg Scour Estimates". *Cold Regions Science and Technology,* Vol. 1 (1980), pp. 223-230.
22. T.R. Chari, S.M. Abdel-Gawad and S.N. Chaudhuri., "Geotechnical Survey of the Sea Floor with a Free Fall penetrometer". Proceedings of POAC '79, *International Conference on Port and Ocean Engineering Under Arctic Conditions,* Trondheim, Aug. 1979, Vol. 2, pp. 835-843.

23. T.R. Chari., "Geotechnical Aspects of Iceberg Scours on Ocean Floors". *Canadian Geotechnical Journal,* Vol. 16, No. 2, May 1979, pp. 379-390.

24. T.R. Chari, K. Muthukrishnaiah, S.N. Guha., "Breakout Resistance of Under-consolidated Sediments". Proceedings of the *First Canadian Conference on Marine Geotechnical Engineering,* Calgary, April 1979, pp. 270-281.

25. T.R. Chari, K. Muthukrishnaiah and A. Zielinski., "Performance Evaluation of a Free Fall Penetrometer". Proceedings of the *First Canadian Conference on Marine Geotechnical Engineering,* Calgary, April 1979, pp. 203-210.

26. S.N. Chaudhuri., "Free Fall Impact Penetration Tests on Soils". *M.Eng. Thesis;* Memorial University of Newfoundland, St. John's, August 1979.

27. A.J. Christian., "Construction Management, Construction Techniques and Other Related Impacts of Offshore Oil and Gas Developments". Paper No. 2, *EAST Report, Faculty of Engineering and Applied Science, Memorial University of Newfoundland, St. John's, January 1982.*

28. A.J. Christian., *"Effects of Oil Industry Development on the Provincial Construction Scene". Annual Meeting of the Association of Professional Engineers of Newfoundland,* Grand Falls, September 1981.

29. A.J. Christian., "The Impact of Offshore Oil Production on the Construction Industry in Sparsely Populated Areas". *3rd International Symposium on Organization and Managemnt of Construction,* Dublin, June 1981, pp. B143-B153.

30. A.J. Christian., "An Introduction to the Impact of the Development and Production of Offshore Oil and Gas on the Newfoundland and Labrador Construction Industry". *EAST Report, Paper No. 1, Faculty of Engineering and Applied Science, Memorial University of Newfoundland, St. John's, April 1981.*

31. N.A. Cochrane., "Automatic Marine Sediment Classification". *Memorial University Contribution to Seabed Research,* Vol. 1 and 2, August 1980.

32. N.A. Cochrane and A.D. Dunsiger., "Sediment Roughness Characteristics Measured by Broadband Spectral Analysis of Acoustic Echoes." Proceedings, *First Canadian Conference on Marine Geotechnical Engineering,* Calgary, April 1979. pp. 140-150.

33. N.A. Cochrane and A.D. Dunsiger., "Seabed Roughness Characterization by Broadband Acoustic Echosounding". Proceedings POAC '79 *International Conf. ence on Port and Ocean Engineering Under Arctic Conditions,* Trondheim, Norway, August 1979, Vol. 2, pp. 877-898.

34. R.T. Dempster., "Prod ıction Platform Construction in Newfoundland", *EAST Report #281. Faculty of Engineering & Applied Science,* Memorial University of Newfoundland, St. John's, October, 1981.

35. R.T. Dempster., "Characteristics of Iceberg Mechanics". *Physics and Mechanics of Ice,* IUTAM Symposium, Ed. P. Tryde, Springer-Verlag, pp. 38-50, 1980.

36. A.D. Dunsiger, N.A. Coch.ne., "Seabed Roughness Characterization by Broadband Acoustic Echosounding". *Canadian Geotechnical Journal,* Volume 18, No. 4, 1981, pp. 475-481.

37. A.D. Dunsiger, N. Cochrane, W.J. Vetter. "Seabed Roughness Characterization from Broadband Acoustic Echosounding with Scattering Models", *IEEE Journal of Oceanic Engineering,* Vol. OE-6, July 1981, No. 3, pp. 94-106.

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39. F.M. El-Hawary, W.J. Vetter., "Heave Compensation of Shallow Marine Seismic Reflection Records by Kalman Filtering". *Oceans '81 Conference Record,* IEEE-MTS Conference, Boston, Sept. 1981, pp. 1062-1066.

40. F.M. El-Hawary., "Modelling and Signal Processing for Identification of Ocean Subsurface Features from Acoustic Reflections". *Ph.D. Thesis,* Memorial University of Newfoundland, St. John's, 1981.

41. F.M. El-Hawary and W.J. Vetter., "Spatial Parameter Estimation for Ocean Subsurface Layered Media". *Canadian Electrical Engineering Journal,* Vol. 5, No. 1, 1980, pp. 28-31.

42. F.M. El-Hawary and W.J. Vetter., "Multiple Reflections of Subsurface Layered Media", *Oceans '80 Conference Record,* IEEE-MTS Conference, Seattle, Sept. 1980, pp. 149-154.

43. M.S. El-Tahan., "Modelling of Iceberg Drift". *M.Eng. Thesis;* Memorial University of Newfoundland, St. John's, April 1980.

44. S.S. Gowda, D.V. Reddy, D.B. Muggeridge and M. Arockiasamy., "Corrosion Fatigue of Offshore Structures". Proceedings *First Indian Conference in Ocean Engineering,* Feb. 1981, pp. V 52-V 61.

45. H.P. Green and T.R. Chari., "Sediment Compaction Below Iceberg Scour Furrows". *Oceans '81 Conference Record,* IEEE-MTS Conference, Boston, September 1981, pp. 223-227.

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47. A.K. Haldar, M. Arockiasamy and D.V. Reddy., "Stochastic Soil-Structure Interaction of Gravity Platforms". *ASCE Engineering Mechanics Division Specialty Conference,* University Texas at Austin, Sept. 1979.

48. A.K. Haldar, D.V. Reddy, M. Arockiasamy and W. Bobby., "Finite Element Nonlinear Seismic Response Analysis of Submarine Pipe-Soil Interaction". Proceedings *International Symposium on Soils Under Cyclic and Transient Loading,* Swansea, U.K., January 1980, pp. 867-877.

49. A.K. Haldar and D.V. Reddy., "Dynamic Finite Element formulation for a Fluid-Saturated Porous Medium". Proceedings *Seventh Canadian Congress of Applied Mechanics* (CANCAM), Sherbrooke, May-June 1979, pp. 901-902.

50. A.K. Haldar, D.V. Reddy and M. Arockiasamy., "Stochastic Seismic Response of a Reactor Building-Foundation-Soil System". Proceedings *Seventh Canadian Congress of Applied Mechanics,* Sherbrooke, May-June, 1979, pp. 377-378.

51. H. Hamza., "Creep, Failue and Fracture of Ice". *Ph.D. Thesis,* Memorial University of Newfoundland, St. John's, August, 1981.

52. H. Hamza and D.B. Muggeridge., "A Numerical Model to Predict the apparent Strength and Fracture Toughness of Viscoelastic Materials and Different Loading Conditions", *5th Canadian Fracture Conference,* Winnipeg, September 1981.

53. H. Hamza, M.C. Singh and D.B. Muggeridge., "The Critical Strain Energy as a Fracture Criterion for Viscoelastic Materials", *5th Canadian Fracture Conference,* Winnipeg, September 1981.

54. H. Hamza and D.B. Muggeridge., "Elastic Creep Bending Analysis of Floating Ice Covers". Proceedings *IAHR International Symposium on Ice,* Quebec City, July 1981, pp. 564-568.

55. H. Hamza and D.B. Muggeridge., "Plane Strain Fracture Toughness (K_{IC}) of Fresh Water Ice". Proceedings of POAC '79, *International Conference on Port and Ocean Engineering Under Arctic Conditions,* Trondheim, Norway, August 1979, pp. 697-707.

56. N.A. Hookey., "The Melting of Vertical Ice Cylinders in Fresh and Saline Water". *Work Term Report,* Memorial University of Newfoundland, St. John's, April 1981.

57. C.C. Hsiung., "Comparison of 3-D Wake Survey Data for Two Models of a Frigate with Different Scales". *Technical Report LTS-SH-290,* Marine Dynamics and Ship Laboratory, National Research Council of Canada, September 1980.

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60. E.S. Large and J. Molgaard., "An Ice Friction Tester Preliminary Design Proposal". *Internal Report,* Faculty of Engineering and Applied Science, Memorial University of Newfoundland, 1980.

61. J.J. Lee., "Melting of a Vertical Ice Wall by Natural Convection into Pure or Saline Water", *M.Eng. Thesis;* Memorial University of Newfoundland, St. John's, August 1979.

62. S.C. Lee and D.V. Reddy., "Frequency Tuning of Offshore Platforms by Liquid Sloshing". *International Conference on Engineering for Protection from Natural Disasters,* Bangkok, Thailand, January 1980.

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66. D.B. Muggeridge and J.J. Murray., "Calibration of a 58 m Wave Flume". *Canadian Society for Civil Engineering Journal,* Vol. 8, No. 4, 1981, pp. 449-455.

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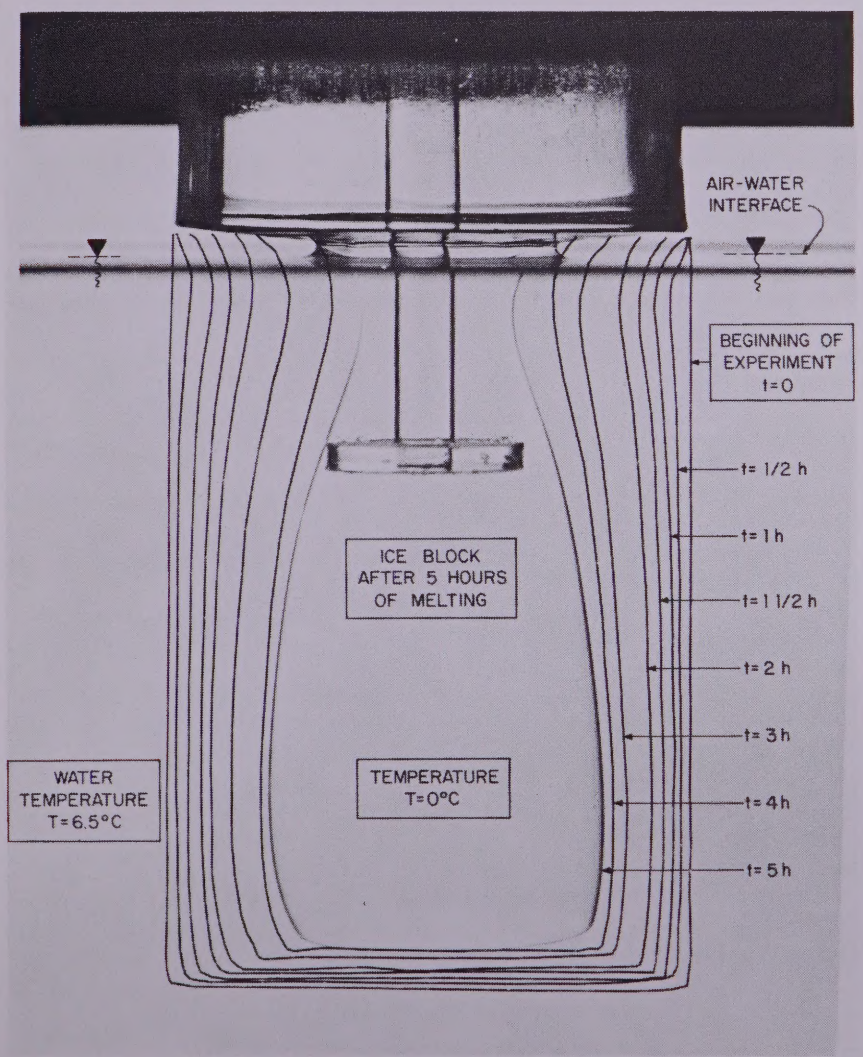

Ice Melting Studies and Profiles at different time intervals.